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SIR ADAM BECK GS NO 1
CHIPPAWA INTAKE
CONCRETE CONDITION SURVEY

Report No. 91-167-K

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ABSTRACT

An investigation, consisting of visual observation, concrete coring and laboratory testing, was carried out to assess the condition of the concrete in Chippawa Intake. In the canal approach wall, gate walls, headblocks, and north and south retaining walls, the concrete is in poor condition and has deteriorated to various depths. Deterioration of the concrete in the walls at the waterline was evident in some locations and may pose structural problems. The diffuser section appeared in better condition, although deteriorated concrete was identified in the piers. Since the concrete in the various structures is non-air-entrained, the deterioration will continue due to freeze/thaw cycling. The sound concrete in the cores had good physical properties, with significantly higher strength than that reported during construction. It is recommended that the structural significance of the deteriorated concrete be assessed and repairs undertaken to ensure the continued serviceability of the various structures.

job	file	date	report no.
42-196-281	842.5 SAB1	October 9, 1991	91-167-K

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To Mr. O. Bernaus
Manager
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Hydraulic Generation Group

Attn: Mr. L.W. Coley/Mr. A.J. Dmochowski

SIR ADAM BECK GS NO 1
CHIPPAWA INTAKE
CONCRETE CONDITION SURVEY

1.0 INTRODUCTION

At the request of Mr. A.J. Dmochowski of the Civil Maintenance Department, an investigation was undertaken by the Civil Research Department to evaluate the condition of the concrete in the various structures comprising Chippawa Intake. The investigation included visual observation, concrete coring and laboratory testing of specimens prepared from the concrete cores. Ultrasonic pulse velocity measurements were made at various locations to assess the condition of the concrete. Selected core holes were also examined with a borehole camera. This report summarizes the results of the investigation.

The field work was carried out from May 7 to 17, 1991. The concrete coring was carried out by the Rock Sciences Section and the remainder of the investigation by the Concrete Technology Section.

2.0 DESCRIPTION OF STRUCTURE

Chippawa Intake is located at the mouth of the Welland River where it joins the Niagara River. The intake is comprised of a canal approach wall, a gate structure for river navigation consisting of east and west headblocks and gate walls, north and south retaining walls and a diffuser section designed to restrict the intake of ice while taking water from the Niagara River for Sir Adam Beck GS No 1 (Figure 1). The intake was constructed in 1922 by a contractor using river-run gravel obtained from the Niagara River near Buffalo, New York. The gravel was graded up to 2-1/2" in size and contained 40% sand. The sand was reported to be lacking fine material.

Three concrete mixes, identified as Classes A, C and D, were used. Class A was used for the construction of the diffuser section, Class C for the walls and headblocks of the gate structure and Class D for the retaining walls. The reported compressive strength and mix proportions for the three classes of concrete are given below.

	Class A	Class C	Class D
Specified Strength 28-Day (psi)	2500	1500	1000
Actual Strength 28-Day (psi)*	2760	1520	1340
Cement Content (lb/yd^3)	613	420	350
Aggregate Content (Volume aggregate/Volume cement)	4	5.5	6.5
W/C Ratio	0.53	0.78	0.94

* The actual strength is the average of tests performed on specimens prepared and tested during construction.

Inspections conducted in 1931 (Report No. LH 60240) and 1935 (Report Nos. LO 4050, LO 4051 and LO 4052) found the concrete to be in generally good condition, with the exception of scaling of the top surface of the headblocks and localized deterioration adjacent to a vertical construction joint in the north retaining wall. Poor quality concrete, due to the lack of mortar caused by segregation during construction, was observed in a few locations.

3.0 FIELD INVESTIGATION

The field investigation consisted of visual observation, concrete coring, nondestructive testing and inspection of selected core holes with a borehole camera. Most of the concrete above the waterline was visually inspected; however, a walkway constructed over the south retaining wall and on the diffuser section restricted access to some locations. It was understood that a diving inspection would be carried out by others to inspect the concrete below the waterline.

Concrete cores were drilled to determine the integrity of the concrete and to obtain specimens for laboratory testing. Most of the cores were drilled to a depth below the waterline. Figure 1 shows the core locations, and Figures 2 and 3 give a description of the condition of the cores. The concrete core log is given in Appendix A. A summary of the field investigation is given below.

In the canal approach wall, surface deterioration of the concrete had occurred at the waterline, on the top of the wall and along a horizontal construction joint (Figure 4). Efflorescence, associated with horizontal construction joints and cracks in the concrete, was present over a large portion of the wall. The areas exhibiting the most significant deterioration were the north end of the wall at the waterline and the area to the south of the pedestrian bridge where the deterioration was associated with a horizontal construction joint and a diagonal crack (Figure 5). A core (Core 6) was drilled vertically from the latter location, and the concrete was found to be cracked to a depth of 410 mm below the surface and from 1020 to 1370 mm. In the vicinity of the waterline (2060 mm), the concrete core was retrieved intact.

Of the two headblocks, the east headblock and associated gate wall (Figure 6) exhibited the most significant concrete deterioration. On the sides of the east headblock, the concrete at the waterline and horizontal construction joints had spalled. In the gate walls, deterioration was evident on the top and sides (Figure 7). Two concrete cores (Cores 2 and 3) were drilled vertically from the east headblock. Core 2, drilled from an area where the most significant deterioration was observed, was retrieved as rubble to a depth of 1850 mm below which the concrete appeared sound. Core 3 was drilled near the centre of the headblock and was recovered as rubble or cracked concrete to a depth of 730 mm. The two cores (Cores 1 and 7) drilled vertically from the gate walls were both recovered as rubble to depths of 760 and 280 mm at which point the drilling was stopped. The concrete in the east gate wall, in particular, was observed to be extensively deteriorated above and at the waterline.

In the south retaining wall, deterioration of the concrete had occurred on both sides of the wall at the waterline and along a horizontal construction joint (Figure 8). Core 4 was drilled vertically from the wall and was recovered in poor condition to a depth of 1400 mm, below which the concrete appeared sound.

At the north end of the south retaining wall, a small wing wall extends at right angle to the diffuser section. This wall was only visually inspected because of difficult access (Figure 9). Where this wall intersects the retaining wall, the concrete at the waterline had deteriorated significantly. A horizontal joint that extends along the length of the wall just above the waterline appeared to be open.

Access to the deck of the diffuser section was restricted by the fence and the asphalt placed for the roadway. From downstream, deterioration was observed at the ends of the deck sections over the piers (Figure 10). Efflorescence, associated with cracks, was evident at other locations in the diffuser section, including the upstream side of the deck sections and the piers (Figures 11 and 12). The piers exhibiting the most significant deterioration, consisting of localized spalls and cracks, were those located on either side of the diffusers which contain vertical construction joints. On the upstream face of the diffuser section, deterioration at the waterline was present in a few localized areas, generally associated with vertical construction joints in the concrete. Poor quality concrete was retrieved in the top 160 mm of Core 5, which was drilled vertically from the upstream end of one of the diffuser piers. Cores 8 and 9, drilled vertically through the deck and into the downstream end of two piers, contained poor quality concrete to depths of 470 and 570 mm, respectively. Two cores (Cores 10 and 11), drilled through the centre of two deck sections consisted of sound concrete.

The north retaining wall exhibited extensive deterioration at the waterline, particularly at the west end (Figures 13 and 14). Deterioration had also occurred along the top and in the vicinity of a vertical crack or joint. Efflorescence associated with horizontal cracks was also present. One core (Core 12) was drilled vertically from the wall and contained poor quality concrete in the upper 240 mm, as well as over an area of approximate 380 mm at the waterline.

An additional section of the retaining wall, extending north from the diffuser section and exposed to the Niagara River, was visually inspected (Figure 15). The concrete in this wall exhibited extensive deterioration at the waterline and along the top of the wall.

Ultrasonic nondestructive testing using the Soniscope was carried out on selected sections of the east headblock, south retaining wall and north retaining wall. At these locations, it was difficult or impossible to transmit a signal through the concrete. This indicated that open cracks or joints probably existed, which was confirmed by the concrete coring. In the south retaining wall, the horizontal joint approximately 1 m below the top of the wall was found to be open. The results of the ultrasonic investigation are not included in this report because of the poor quality of the signals received.

A camera survey of selected boreholes was carried out to evaluate the in situ condition of the concrete. It was found that the sections of cores recovered as rubble corresponded to cracked concrete in the structure. In addition, the locations where water was lost during drilling corresponded to cracks or open construction joints.

4.0 LABORATORY TESTING

Specimens were prepared from the sound concrete in the cores. The specimens were tested in the laboratory for compressive strength, absorption, density and ultrasonic pulse velocity. The test results are given in Figures 2 and 3. The concrete was also petrographically examined and the data sheets are given in Appendix B.

The compressive strength was determined using test procedure CAN/CSA-A23.2-14C. The specimens were prepared with a length to diameter ratio of two and were 88 mm in diameter, with the exception of specimens from Cores 3, 10 and 11 which were 96 mm in diameter. The compressive strength of the concrete, tested in a saturated surface dry condition, ranged from 35.3 to 68.3 MPa and averaged 50.3 MPa.

The absorption after immersion was determined using test procedure ASTM 642. The absorption ranged from 3.9% to 6.4% and averaged 5.1%. An absorption in the range of 4% to 6% is generally associated with good quality concrete.

Ultrasonic pulse velocity measurements were made on the compressive strength specimens prior to capping and testing. With the exception of one specimen, the ultrasonic pulse velocity of the concrete, in a saturated surface dry condition, ranged between 4670 and 5020 m/s and averaged 4800 m/s. These values are in the range generally associated with good quality concrete. One specimen had a velocity of 3860 m/s, which was significantly lower than the other specimens; however, the compressive strength and density of this specimen were similar to the others.

The density was determined on saturated surface dry concrete and ranged from 2281 to 2447 kg/m^3, with an average value of 2398 kg/m^3.

Sections of five cores were examined petrographically. The aggregate consisted of a 20 mm nominal size gravel, with some 40 mm pieces. The coarse aggregate consisted primarily of limestone/dolomite with relatively high fractions (up to 30% to 40%) of chert as cherty carbonates. Quartzite, gneiss, sandstone and volcanics were also present. Voids in the concrete were estimated to be 1% to 3% by volume, which is typical for non-air-entrained concrete. Cracks in the concrete were localized, with more cracks present near the top of the cores. The presence of alkali-silica gel was observed in a couple of the specimens, but was not prevalent in the cores examined.

5.0 DISCUSSION

The inspection concentrated on the concrete at and above the waterline. This area is generally exposed to the most severe exposure condition and is therefore most likely to exhibit deterioration. Drilling relatively shallow (ie, 2 m deep) core holes and concentrating on the concrete above and at the waterline also allowed for a greater area to be investigated. Areas below the waterline, which exhibit deterioration, will be identified by the diving inspection.

As expected, deterioration of the concrete had progressed since the inspections conducted in 1931 and 1935. The deterioration was concentrated at the waterline and along horizontal and vertical joints. Efflorescence, caused by water flowing through cracks and joints in the concrete, was observed in many locations. In the canal approach wall, gate walls, headblocks, and north and south retaining walls, the coring indicated that to various depths the concrete was in poor condition. The diffuser section including the decks appeared in better condition, with the exception of the piers that contained some poor quality concrete.

In the cores, the sound concrete encountered exhibited good physical properties and had developed significantly higher strength than that reported during construction.

The mechanism causing the deterioration of this concrete appears to be freeze/thaw cycling. The age of the structure (constructed in 1922) and the petrographic examination of the cores confirm that the concrete is non-air-entrained. The deterioration is therefore expected to continue. Although much of the surface concrete may be cracked or deteriorated, the most significant problem appears to be the deterioration at the waterline, which is occurring in some of the walls. This was particularly evident in the west end of the north retaining wall.

6.0 CONCLUSIONS

The investigation indicates that, in the canal approach wall, gate walls, headblocks and north and south retaining walls, the concrete is in poor condition and has deteriorated to various depths below the surface. A more significant problem, particularly in the walls, may be the deterioration that has occurred at the waterline. Since the concrete is non-air-entrained, the deterioration will continue due to freeze/thaw cycling. The significance of the deteriorated concrete should be evaluated and repairs undertaken as required to ensure the continued serviceability of the structures.

Generally, the concrete in the diffuser section appeared to be in better condition, although deteriorated concrete was identified in the piers. The presence of an asphalt roadway prevented a visual inspection of the deck from being performed.

The sound concrete in the cores obtained from the structures exhibited good physical properties, with significantly higher compressive strength than that reported during construction.

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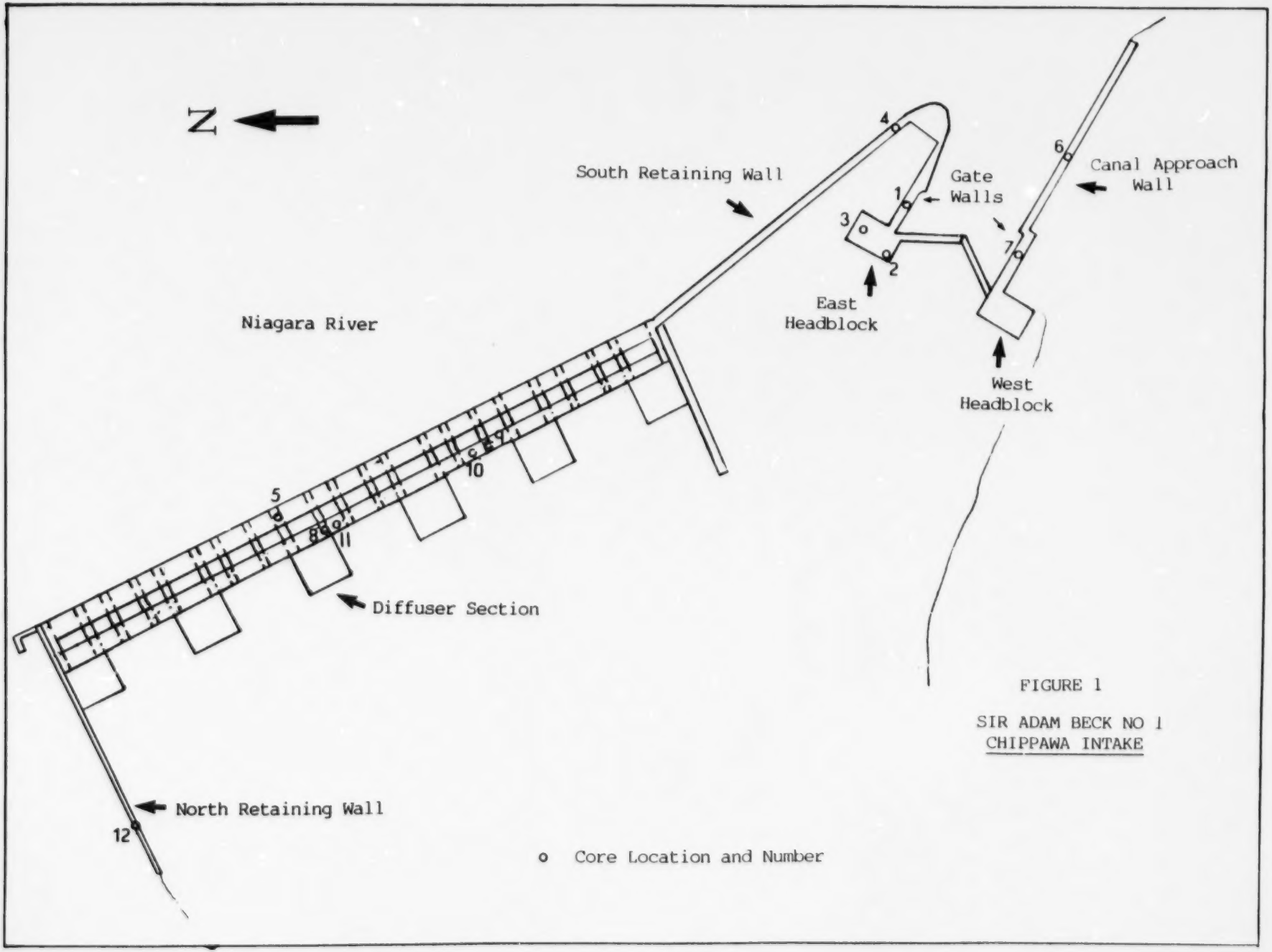

FIGURE 1

SIR ADAM BECK NO 1
CHIPPAWA INTAKE

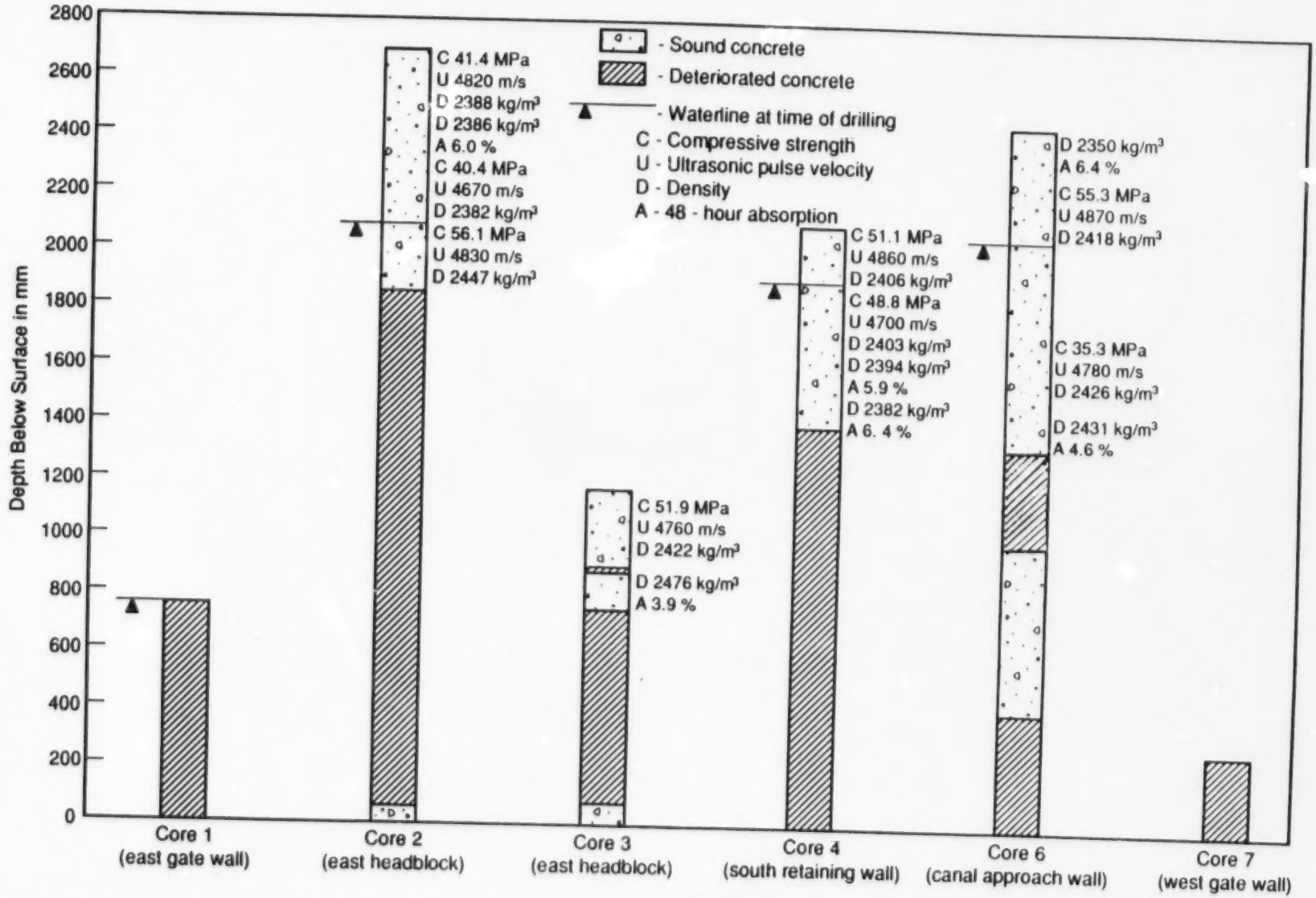

FIGURE 2

SIR ADAM BECK GS NO 1
CHIPPAWA INTAKE
DESCRIPTION OF CONCRETE CORES

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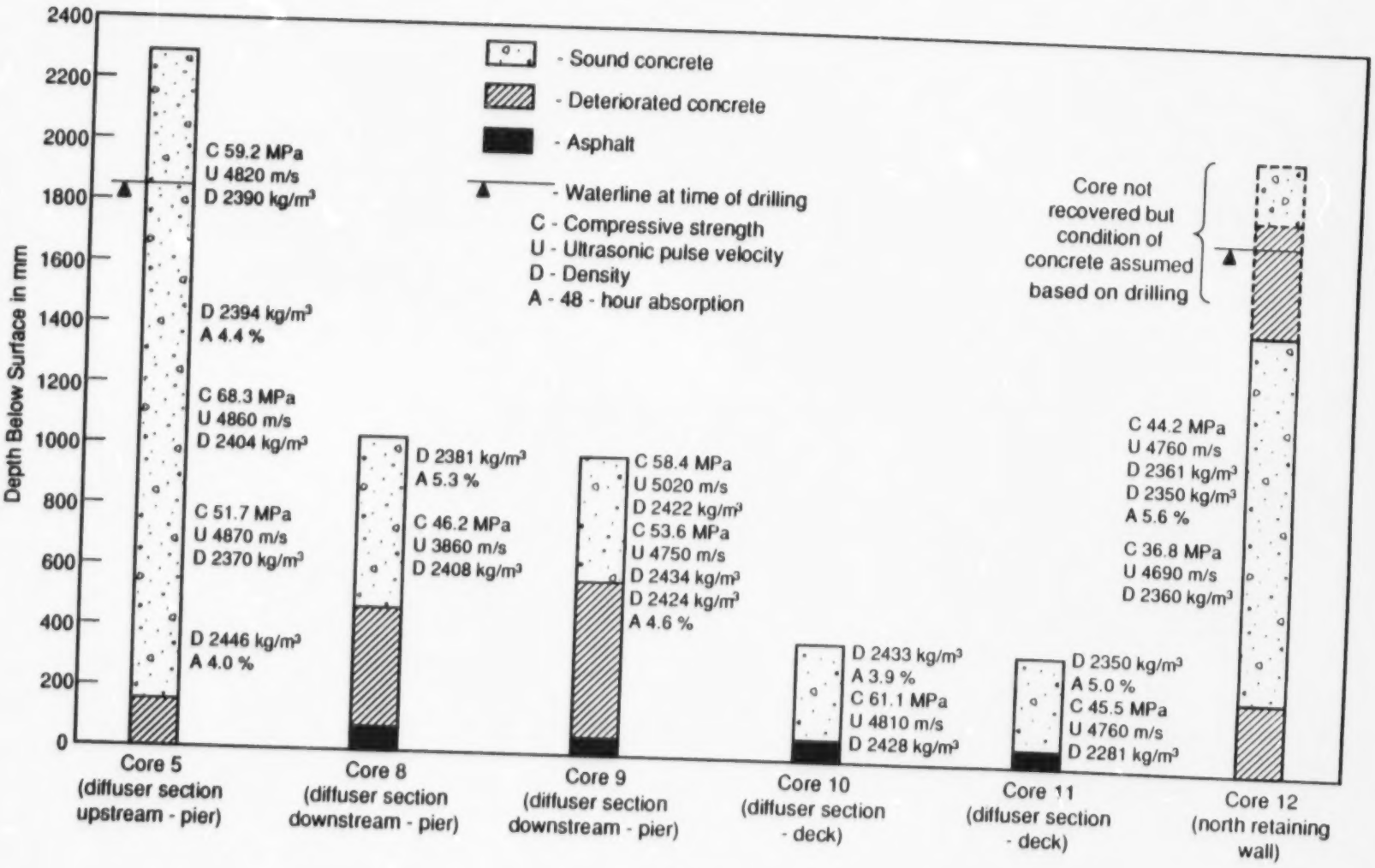

FIGURE 3

SIR ADAM BECK GS NO 1
CHIPPAWA INTAKE
DESCRIPTION OF CONCRETE CORES

Figure 4: In the canal approach wall, deterioration had occurred at the waterline, on the top of the wall and along a horizontal construction joint. Efflorescence was present over a large part of the wall.

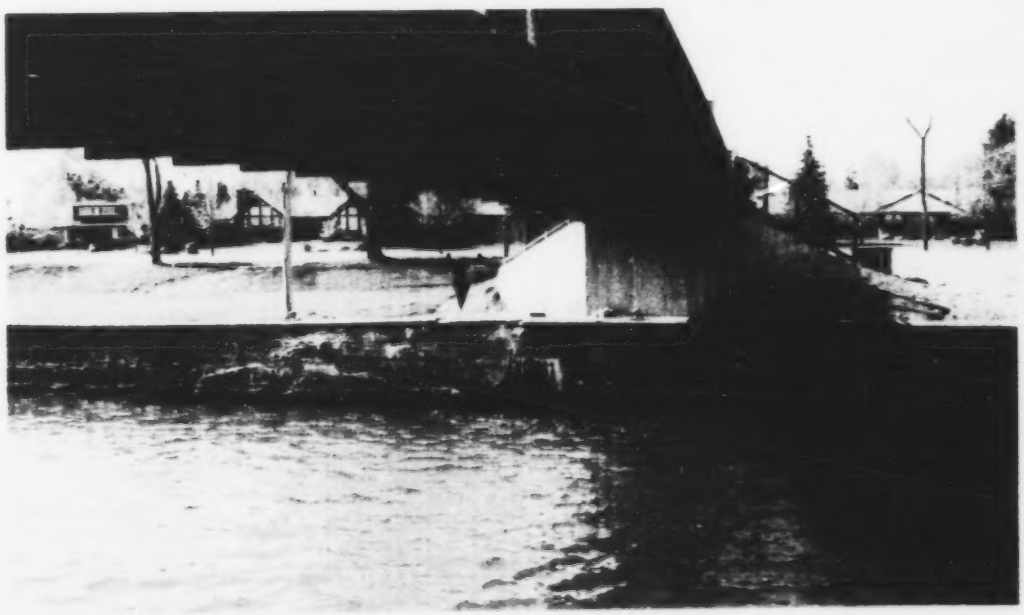

Figure 5: The most significant deterioration evident in the canal approach wall was associated with a horizontal construction joint and a diagonal crack in the wall. The location of Core 6, which was drilled vertically to a depth below the waterline, is shown.

Figure 6: In the east headblock and gate wall, deterioration of the concrete had occurred at the waterline and along horizontal construction joints. The edges and top of the gate wall had also extensively deteriorated.

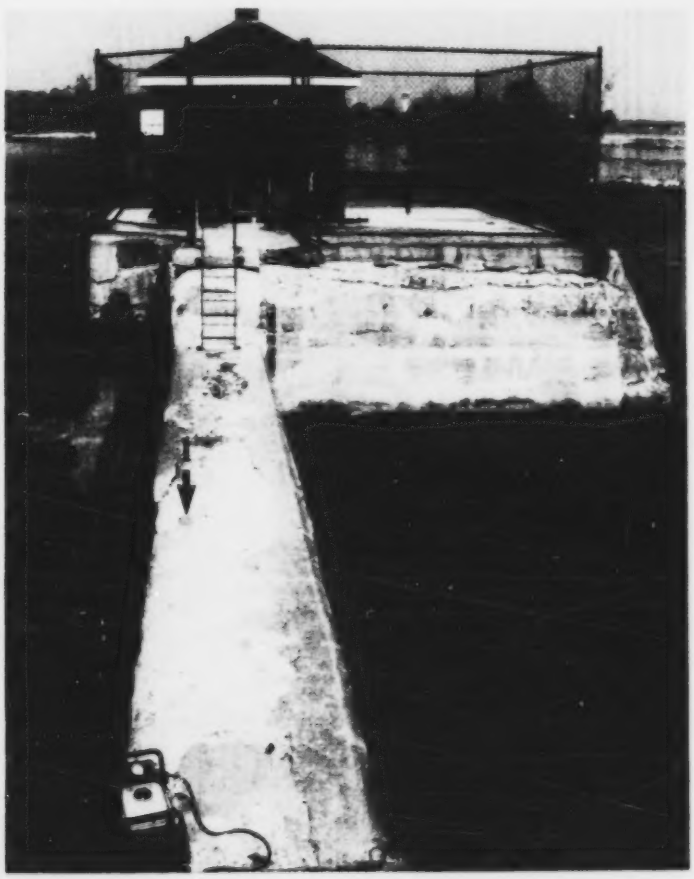

Figure 7: Deterioration was evident in the east headblock and gate wall. The locations of Cores 1 to 3 are shown.

Figure 8: On both sides of the south retaining wall, deterioration had occurred at the waterline and along a horizontal construction joint.

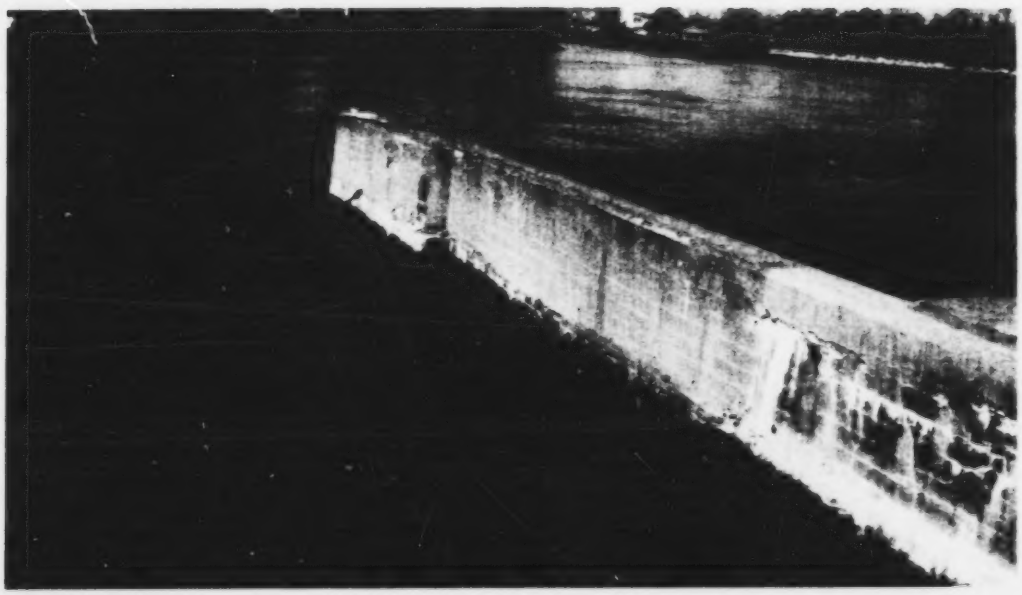

Figure 9: The small wing wall at the north end of the south retaining wall was extensively deteriorated where it intersected the retaining wall. A horizontal joint just above the waterline also appeared to be open.

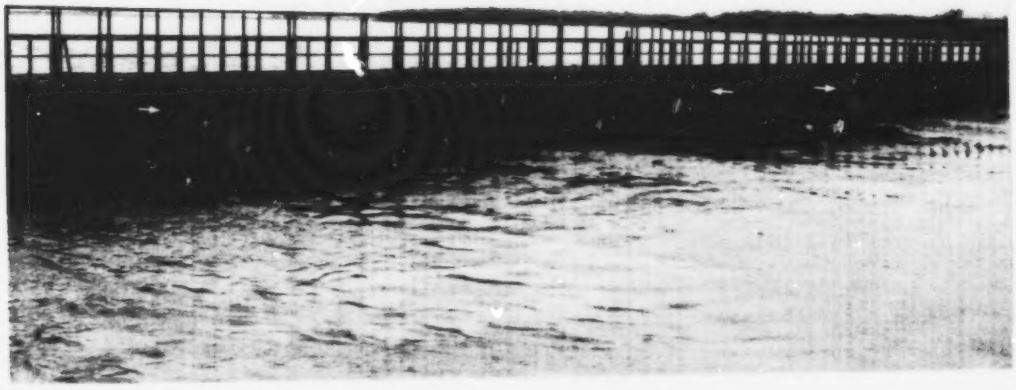

Figure 10: On the downstream side of the diffuser section, deterioration was evident at the ends of the deck sections over the piers.

Figure 11: Spalled concrete, cracks and efflorescence were observed in the upstream face of the deck sections and in the piers (particularly the piers containing vertical construction joints such as the one shown) in the diffuser.

Figure 12: Efflorescence associated with cracks in the upstream face of the deck section of the diffuser.

Figure 13: Deterioration of the concrete in the north retaining wall was most severe at the waterline, particularly at the west end of the wall.

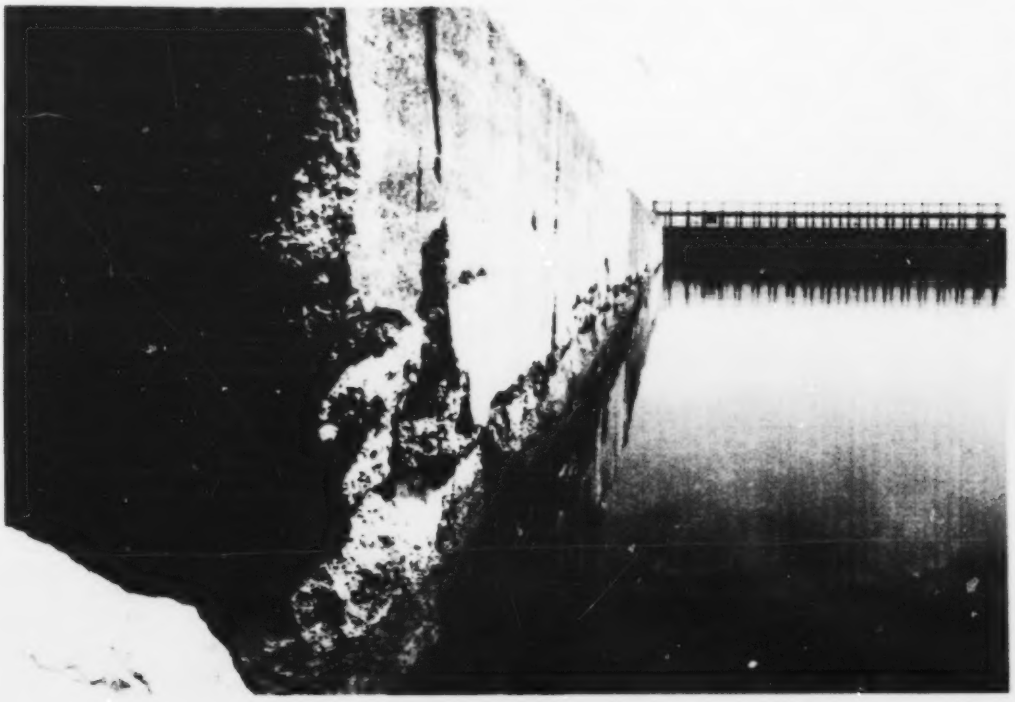

Figure 14: The west end of the north retaining wall exhibited significant deterioration at the waterline.

Figure 15: The retaining wall north of the diffuser section facing the Niagara River was deteriorated at the waterline and along the top edge.

APPENDIX A

SIR ADAM BECK GS NO 1
CHIPPAWA INTAKE
CONCRETE CORE LOG

SIR ADAM BECK GS NO 1
CHIPPAWA INTAKE
CONCRETE CORE LOG

Concrete cores were drilled from various locations to determine the integrity of the concrete and to provide specimens for laboratory testing. Most of the cores were drilled to a depth below the waterline. The waterline at the site was found to vary as much as 300 mm over a few days. In some locations, for various reasons, the drilling was terminated before sound concrete was encountered. The upper portion of the cores was 96 mm in diameter and the lower portion was 88 mm diameter.

The core locations are shown in Figure 1 and photos of the cores are given in Figures A1 to A3.

Core 1 (east gate wall)

0 - 760 mm - core recovered as rubble

- The core was drilled vertically from the east gate wall. The concrete in this wall exhibited extensive surface deterioration.
- The core was drilled 380 mm from the canal side of the wall.
- The concrete in the wall from 250 to 460 mm was observed to consist of rubble.
- The drilling was stopped because the poor quality of the concrete caused the drill to vibrate loose from its anchorage.
- The waterline during drilling was at 760 mm.
- A horizontal construction joint in the wall at the waterline was found to be open.

Core 2 (east headblock)

0 - 60 mm	-	repair concrete placed on top of headblock (well bonded) repair contained wire mesh
60 - 480 mm	-	concrete extensively cracked
480 - 1850 mm	-	core recovered as rubble
810 mm	-	lost drilling water
1850 - 2690 mm	-	sound concrete
2180 mm	-	horizontal construction joint

- The core was drilled vertically from the northwest corner of the east headblock. The sides of the headblock in the northwest corner exhibited extensive surface deterioration.
- The core was drilled 650 mm from the edge of the headblock.
- The waterline during drilling was at 2080 mm.

Core 3 (east headblock)

0 - 80 mm	-	repair concrete placed on top of headblock (well bonded)
		repair contained wire mesh
80 - 270 mm	-	concrete extensively cracked
270 - 530 mm	-	core recovered as rubble
530 - 730 mm	-	concrete cracked
730 - 880 mm	-	sound concrete
810 mm	-	lost drilling water
880 - 900 mm	-	honeycombed section of concrete
900 - 1170 mm	-	sound concrete
	-	contacted wood at 1170 mm

- The core was drilled vertically from near the centre of the east headblock.
- The drilling was stopped because of contact with wood.
- A debonded horizontal construction joint or crack was identified at 810 mm.

Core 4 (south retaining wall)

0 - 450 mm	-	concrete extensively cracked
450 - 1100 mm	-	core recovered as rubble
990 mm	-	lost drilling water
1100 - 1400 mm	-	core recovered in broken sections (questionable quality)
1400 - 2100 mm	-	sound concrete

- The core was drilled vertically from the middle near the south end of the south retaining wall. On the upstream side of the wall, deterioration of the concrete was evident from 900 to 1800 mm.
- The waterline during drilling was at 1900 mm.
- A debonded horizontal construction joint was identified approx 1000 mm below the top of the wall.

Core 5 (diffuser section - pier)

0 - 160 mm	-	concrete cracked
160 - 2290 mm	-	sound concrete
990 mm	-	lost drilling water
1730 mm	-	intersected 13 mm diameter steel bar

- The core was drilled vertically from the upstream end of Pier 14 (piers numbered from south to north) of the diffuser section. Deterioration was evident on the side of the pier near the waterline.
- The core was drilled to the south of the vertical construction joint in the pier and 800 mm from the upstream face.
- The waterline during drilling was at 1850 mm.
- The loss of water at 990 mm appeared to be associated with open cracks in the structure.

Core 6 (canal approach wall)

0 - 410 mm	-	core recovered as rubble or in cracked sections
410 - 1020 mm	-	sound concrete
1020 mm	-	lost drilling water
1020 - 1370 mm	-	concrete cracked
1370 - 2460 mm	-	sound concrete

- The core was drilled vertically from the canal approach wall in an area exhibiting extensive surface deterioration along the side of the wall.
- The core was drilled south of the foot bridge over the canal and 420 mm from the face of the wall.
- The waterline during drilling was at 2060 mm.

Core 7 (west gate wall)

0 - 280 mm	-	core recovered as rubble
280 - 410 mm	-	core drilled, but not recovered

- The core was drilled vertically from the west gate wall in an area exhibiting surface deterioration.
- The core was drilled 380 mm from the face of the wall.
- The waterline during drilling was at 990 mm.

Core 8 (diffuser section - pier)

0 - 80 mm	-	asphalt roadway
80 - 330 mm	-	core recovered as rubble
330 - 470 mm	-	concrete extensively cracked
470 - 1040 mm	-	sound concrete

- The core was drilled vertically from the downstream end of Pier 13 (piers numbered from south to north) of the diffuser section.
- The core was drilled 300 mm from the north side and 660 mm from the downstream end of the pier.

Core 9 (diffuser section - pier)

0 - 55 mm	-	asphalt roadway
55 - 570 mm	-	core recovered as rubble
330 mm	-	intersected 13 mm diameter steel bar
570 - 990 mm	-	sound concrete

- The core was drilled vertically from the downstream end of Pier 7 (piers numbered from south to north) of the diffuser section.
- The core was drilled in approximately the centre of the pier, 820 mm from the downstream end.

Core 10 (diffuser section - deck)

0 - 75 mm	-	asphalt roadway
75 - 320 mm	-	sound concrete
320 - 390 mm	-	sound concrete, core lost into river

- The core was drilled vertically through the deck of the diffuser section between Piers 7 and 8 (piers numbered from south to north).
- The core was drilled approximately in the centre of the deck.

Core 11 (diffuser section - deck)

0 -60 mm	-	asphalt roadway
60 - 310 mm	-	sound concrete
310 - 370 mm	-	sound concrete, core lost into river

- The core was drilled vertically through the deck of the diffuser section between Piers 12 and 13 (pier numbered from south to north).
- The core was drilled approximately in the centre of the deck.

Core 12 (north retaining wall)

0 - 240 mm	-	core recovered as cracked concrete and rubble
240 - 1450 mm	-	sound concrete
1450 - 1570 mm	-	core recovered as rubble
1570 - 1830 mm	-	core not recovered, but assumed to be rubble
1830 - 2030 mm	-	core not recovered, but assumed to be sound concrete

- The core was drilled vertically near the west end of the north retaining wall. The surface concrete on the face of the wall from 1400 to 1750 mm was deteriorated.
- The core was drilled 560 mm from the face of the wall.
- The waterline during drilling was 1750 mm.
- The core was drilled to a depth of 2030 mm; however, 1570 mm of core was recovered. The remainder of the core could not be retrieved.

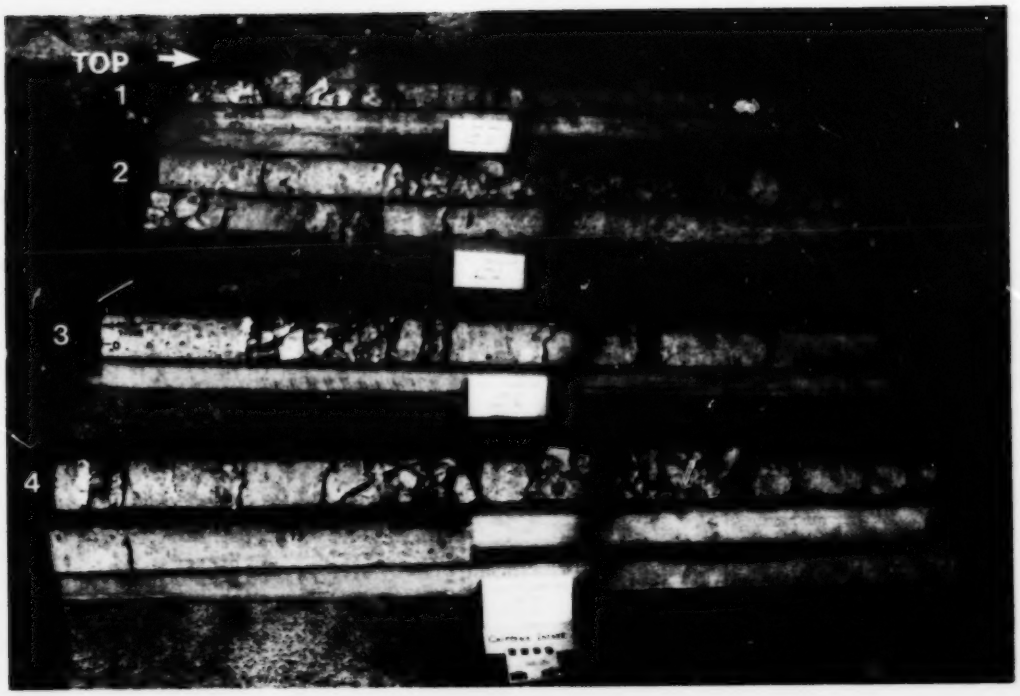

Figure A1 Cores 1 to 4 drilled from various locations at Chippawa Intake.

Figure A2 Cores 5 to 8 drilled from various locations at Chippawa Intake.

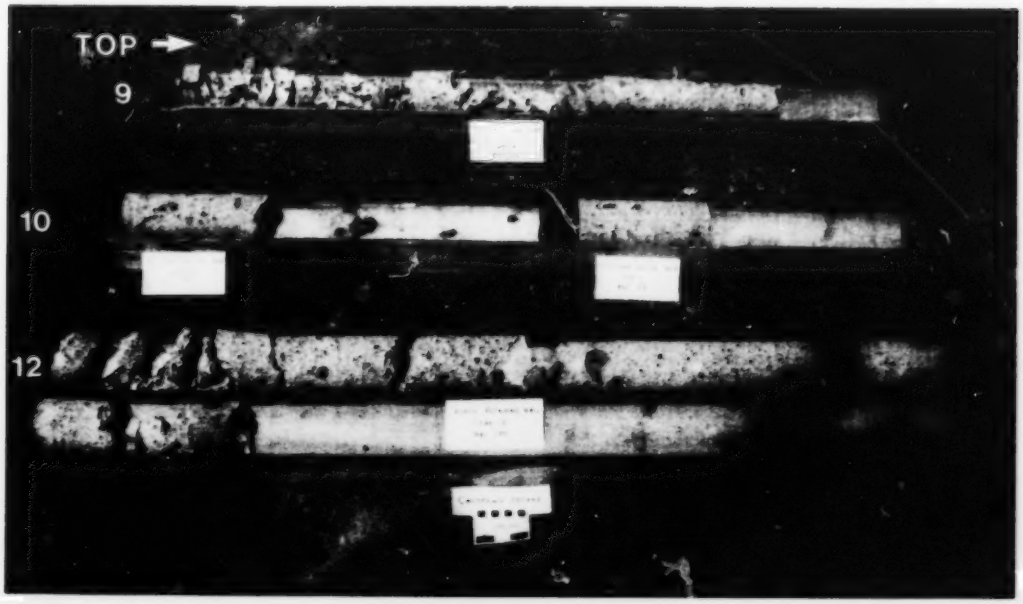

Figure A3 Cores 9 to 12 drilled from various locations at Chippawa Intake.

APPENDIX B

SIR ADAM BECK GS NO 1
CHIPPAWA INTAKE
PETROGRAPHIC EXAMINATION OF CONCRETE CORES

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
ADAPTED FROM: ASTM C 856

Project: SIR ADAM BECK GS 1 - CHIPPAWA INTAKE Job No.: 42-196-281
Region : CENTRAL Area: LINCOLN File No.: 842.5 SAB
Structure: INTAKE STRUCTURE Report No.: SN91-22-K Date Issued: 91.07.15

Sample Type : Core[X] Cylinder[ ] Chunk[ ] Other[ ]

Sample Description: Section (approx.int. 200 to 300 mm, nominal 96 mm diamter) of Core 4 drilled vertically from the intake structure. The concrete has undergone approx.70 years of exposure in an environment of high rel. humidity.

* Sample Preparation: Freshly broken/saw cut/drilled surface[X] Polished face[ ]
Weathered surface[ ] Thin Section[ ]/No.

CONCRETE

Hit with hammer : Ring[ ] Dull[X]
Break with fingers : Particles not dislodged[ ] Powdery[X] Friable[ ]
During sawing : Clean cut[ ] Breaks easily[ ]
Cement/coarse aggregate bond: Good[ ] Partial[X] Poor[ ]
Cement/fine aggregate bond : Good[ ] Partial[X] Poor[ ]
Presence of honeycombing : Not observed[ ] Minor[X] Extensive[ ]

COARSE AGGREGATE

Source : River-run, Niagara River, Buffalo, N.Y.
% of total volume : 45-55 % Visual estimate[X] Point count[ ]
Material type : Gravel[X] Quarried[ ] Mixture[ ] Other[ ]
Shape : Rounded[X] Partly crushed[ ] 100% Crushed[ ]
Distribution : Even[X] Uneven[ ] Chaotic[ ]
Nominal size : 20 (mm)
Maximum size : 20 (mm)
* Preferred orientation: Present[X] Not observed[ ]

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS/GEL/ FRACTURES	REMARKS
Limestone/ dolomite	60-70	Several fractured particles. Fractures extend into cement paste.	Rims of gel/calcium carb. and portlandite were noted on particles at the core breaks.
Chert or cherty carbonates.	10-15	None.	Same as above.
Sandstone	10-15	None.	Same as above.
Gneiss	10-15	None.	Same as above.
Quartzite	10-15	None.	Same as above.

FINE AGGREGATE

Source : River-run, Niagara River, Buffalo, N.Y.
% of total volume : 30-40 % Visual estimate[X] Point count[ ]
Material type : Natural[X] Manufactured [ ] Mixture[ ] Other[ ]
Shape : Rounded[X] Subrounded[ ] Subangular[ ] Angular[ ]
Distribution : Even[X] Uneven[ ] Chaotic[ ]
Preferred orientation: Present[ ] Not observed[X]

CEMENT MATRIX

% of total volume : 10-20 % Visual estimate[X] Point count[
Appearance of broken surface: Subtransluescent[ ] Dull[X] Chalky[X]
Colour : Grey[ ] Light grey[X] White[ ] Brown[X] Other:
Colour distribution: Even[X] Mottled[ ] Gradational[
Bleeding : Extensive[ ] Minor[X] Not observed[
Carbonation : Surficial only[ ] Along fractures[ ] Partial[ ] Total[ ]
Slag cement : Observed[ ] Not observed[X]
Fly ash : Observed[ ] Not observed[X]

VOIDS

% of total volume : 1-3 % Visual estimate[X] Point count[
Distribution : Even[ ] Uneven[X] Clustered[ ]
Shape : Spherical[ ] Nonspherical[ ] Ellipsoidal[ ] Irregular[X]
Entrained air : Air-entrained[ ] Non-air-entrained[X]
Interior lustre : Dull[X] Shining[ ]
Interior condition: Empty[X] Lined[ ] Partly filled[ ] Totally filled[ ]
% Voids with mineralization: Most[ ] About half[ ] Few[ ] None[X]
Mineralization : Alkali-silica gel[ ] Ettringite[ ] Portlandite[
Calcium carbonate[ ]

CRACKS

Amount : Extensive[X] Occasional[ ] None[ ]
Continuity and Distribution: A series of subparallel cracks which extend across the width of the core and are orientated perpendicular to direction of concrete placement
Orientation : Vertical[ ] Horizontal[X] Random[ ]
Location : Through aggregate particles[X] Around aggregate particles[X]
Width (mm) : Range 0.1 to 0.3 Average 0.2
% filled : < 10 %
Filling material: Alkali-silica gel[X] Ettringite[ ] Portlandite[X]
Calcium carbonate[X] Other:
Associated with embedded items: Yes[ ] No[X]

EMBEDDED ITEMS Yes[ ] No[X]

Description:
Condition : Clean[ ] Corroded[ ] Decayed[ ]
Size (mm) :
Location/Orientation:
Other :

GENERAL COMMENTS: * Results are based on a visual examination of a core sectio only, and not all items listed above could be evaluated.
** Several elongated particles are orientated with their long axis perpendicular to the direction of concrete placement.

Distribution: ~~Mr. E.J. McColm~~ ~~Civil Research~~
Mr. J. Vitanyi Civil Research
Mr. M.F. Everitt Civil Research
842.5 SAB KR163
842.5 (P) Official Record

Approved by: _____ Submitted by: _____
Report No.: SN91-22-K

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
ADAPTED FROM: ASTM C 856

Project: SIR ADAM BECK GS 1 - CHIPPAWA INTAKE Job No.: 42-196-281
Region : CENTRAL Area: LINCOLN File No.: 842.5 SAB
Structure: INTAKE STRUCTURE Report No.: SN91-23-K Date Issued: 91.07.15

Sample Type : Core[X] Cylinder[ ] Chunk[ ] Other[ ]

Sample Description: Section (int. 1370 to 2460 mm, nominal 88 mm diameter) of core 6 drilled vertically from the canal approach wall.The concrete has undergone approx. 70 years of exposure in an environment of high relative humidity.

*Sample Preparation: Freshly broken/saw cut/drilled surface[X] Polished face[ ]
Weathered surface[ ] Thin Section[ ]/No.

CONCRETE

Hit with hammer	: Ring[X]	Dull[ ]		
Break with fingers	: Particles not dislodged[X]	Powdery[ ]	Friable[ ]	
During sawing	: Clean cut[ ]	Breaks easily[ ]		
Cement/coarse aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Cement/fine aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Presence of honeycombing	: Not observed[X]	Minor[ ]	Extensive[ ]	

COARSE AGGREGATE

Source	: River-run, Niagara River, Buffalo, N.Y.			
% of total volume	: 60-70 %	Visual estimate[X]		Point count[ ]
Material type	: Gravel[X]	Quarried[ ]	Mixture[ ]	Other[ ]
Shape	: Rounded[X]	Partly crushed[ ]	100% Crushed[ ]	
Distribution	: Even[X]	Uneven[ ]		Chaotic[ ]
Nominal size	: 20 (mm)			
Maximum size	: 20 (mm)			
*Preferred orientation	: Present[X]	Not observed[ ]		

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS/GEL/ FRACTURES	REMARKS
Limestone/ dolomite.	30-40	None.	--
Gneiss	30-40	Same as above.	--
Chert or cherty carbonates.	15-20	Same as above.	--
Sandstone	10-15	Same as above.	--
Quartzite	5-10	Same as above.	--
Volcanic	0-5	Same as above.	--

FINE AGGREGATE

Source	: River-run, Niagara River, Buffalo, N.Y.				
% of total volume	: 10-20 %	Visual estimate[X]			Point count[ ]
Material type	: Natural[X]	Manufactured [ ]	Mixture[ ]		Other[ ]
Shape	: Rounded[X]	Subrounded[ ]	Subangular[ ]	Angular[ ]	
Distribution	: Even[X]	Uneven[ ]			Chaotic[ ]
Preferred orientation	: Present[ ]	Not observed[X]			

CEMENT MATRIX

% of total volume : 5-10 % Visual estimate[X] Point count[ ]
Appearance of broken surface: Subtransluescent[ ] Dull[X] Chalky[ ]
Colour : Grey[ ] Light grey[X] White[ ] Brown[X] Other:
Colour distribution: Even[X] Mottled[ ] Gradational[ ]
Bleeding : Extensive[ ] Minor[ ] Not observed[X]
Carbonation : Surficial only[ ] Along fractures[ ] Partial[ ] Total[ ]
Slag cement : Observed[ ] Not observed[X]
Fly ash : Observed[ ] Not observed[X]

VOIDS

% of total volume : 1-3 % Visual estimate[X] Point count[ ]
Distribution : Even[ ] Uneven[X] Clustered[ ]
Shape : Spherical[ ] Nonspherical[ ] Ellipsoidal[ ] Irregular[X]
Entrained air : Air-entrained[ ] Non-air-entrained[X]
Interior lustre : Dull[X] Shining[ ]
Interior condition: Empty[X] Lined[ ] Partly filled[ ] Totally filled[ ]
% Voids with mineralization: Most[ ] About half[ ] Few[ ] None[X]
Mineralization : Alkali-silica gel[ ] Ettringite[ ] Portlandite[ ]
Calcium carbonate[ ]

CRACKS

Amount : Extensive[ ] Occasional[ ] None[X]
Continuity and Distribution:

Orientation : Vertical[ ] Horizontal[ ] Random[ ]
Location : Through aggregate particles[ ] Around aggregate particles[ ]
Width (mm) : Range to Average
% filled : %
Filling material: Alkali-silica gel[ ] Ettringite[ ] Portlandite[ ]
Calcium carbonate[ ] Other:
Associated with embedded items: Yes[ ] No[ ]

EMBEDDED ITEMS Yes[ ] No[X]

Description:
Condition : Clean[ ] Corroded[ ] Decayed[ ]
Size (mm) :
Location/Orientation:
Other :

GENERAL COMMENTS: * Results are based on a visual examination of a core sectio only, and not all items listed above could be evaluated.
** Several elongated particles are orientated with their long axis perpendicular to the direction of concrete placement.

Distribution: ~~Mr. E.J. McCol~~
Mr. J. Vitanyi
Mr. M.F. Everitt
842.5 SAB
842.5 (P)
~~Civil Research~~
Civil Research
Civil Research
KR 163
Official Record

Approved by: _____

Submitted by: _____
Report No.: SN91-28-K

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
ADAPTED FROM: ASTM C 856

Project: SIR ADAM BECK GS 1 - CHIPPAWA INTAKE Job No.: 42-196-281
Region : CENTRAL Area: LINCOLN File No.: 842.5 SAB
Structure: DIFFUSER SECT. PIER Report No.: SN91-24-K Date Issued: 91.07.15

Sample Type : Core[X] Cylinder[ ] Chunk[ ] Other[ ]

Sample Description: Section(approx.int. 230 to 330 mm, nominal 96 mm diameter) of Core 9 drilled vertically from a diffuser section pier. The concrete has undergone approx.70 years of exposure in an environment of high rel. humidity.

*Sample Preparation: Freshly broken/saw cut/drilled surface[X] Polished face[ ]
Weathered surface[ ] Thin Section[ ]/No.

CONCRETE

Hit with hammer	: Ring[ ]	Dull[X]		
Break with fingers	: Particles not dislodged[ ]	Powdery[X]	Friable[ ]	
During sawing	: Clean cut[ ]	Breaks easily[ ]		
Cement/coarse aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Cement/fine aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Presence of honeycombing	: Not observed[X]	Minor[ ]		Extensive[ ]

COARSE AGGREGATE

Source	: River-run, Niagara River, Buffalo, N.Y.				
% of total volume	: 45-55 %	Visual estimate[X]		Point count[ ]	
Material type	: Gravel[X]	Quarried[ ]	Mixture[ ]		Other[ ]
Shape	: Rounded[X]	Partly crushed[ ]		100% Crushed[ ]	
Distribution	: Even[X]	Uneven[ ]			Chaotic[ ]
Nominal size	: 20 (mm)				
Maximum size	: 40 (mm)				
Preferred orientation	: Present[ ]	Not observed[X]			

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS/GEL/ FRACTURES	REMARKS
Limestone/ dolomite.	50-60	Several fractured particles. Fractures extend into the cement paste.	Rims of gel,calcium carb. and portlandite were noted at the core breaks.
Chert or cherty carbonates.	10-15	Same as above.	Same as above.
Sandstone	10-15	None.	Same as above.
Gneiss	10-15	None.	Same as above.
Quartzite	10-15	None.	Same as above.

FINE AGGREGATE

Source	: River-run, Niagara River, Buffalo, N.Y.				
% of total volume	: 30-35 %	Visual estimate[X]		Point count[ ]	
Material type	: Natural[X]	Manufactured [ ]	Mixture[ ]		Other[ ]
Shape	: Rounded[X]	Subrounded[ ]	Subangular[ ]		Angular[ ]
Distribution	: Even[X]	Uneven[ ]			Chaotic[ ]
Preferred orientation	: Present[ ]	Not observed[X]			

CEMENT MATRIX

% of total volume : 20-25 % Visual estimate[X] Point count[ ]
Appearance of broken surface: Subtransluescent[ ] Dull[X] Chalky[ ]
Colour : Grey[ ] Light grey[X] White[ ] Brown[X] Other:
Colour distribution: Even[X] Mottled[ ] Gradational[ ]
Bleeding : Extensive[ ] Minor[ ] Not observed[X]
Carbonation : Surficial only[ ] Along fractures[ ] Partial[ ] Total[ ]
Slag cement : Observed[ ] Not observed[X]
Fly ash : Observed[ ] Not observed[X]

VOIDS

% of total volume : 1-3 % Visual estimate[X] Point count[ ]
Distribution : Even[ ] Uneven[X] Clustered[ ]
Shape : Spherical[ ] Nonspherical[ ] Ellipsoidal[ ] Irregular[X]
Entrained air : Air-entrained[ ] Non-air-entrained[X]
Interior lustre : Dull[X] Shining[ ]
Interior condition: Empty[X] Lined[ ] Partly filled[ ] Totally filled[ ]
% Voids with mineralization: Most[ ] About half[ ] Few[ ] None[X]
Mineralization : Alkali-silica gel[ ] Ettringite[ ] Portlandite[ ]
Calcium carbonate[ ]

CRACKS

Amount : Extensive[ ] Occasional[X] None[ ]
Continuity and Distribution: Severl subparallel cracks which extend across the width of the core and orientated perpendicular to the direction of concrete placement.
Orientation : Vertical[ ] Horizontal[X] Random[ ]
Location : Through aggregate particles[X] Around aggregate particles[X]
Width (mm) : Range 0.1 to 0.3 Average 0.2
% filled : < 10 %
Filling material: Alkali-silica gel[X] Ettringite[ ] Portlandite[X]
Calcium carbonate[X] Other:
Associated with embedded items: Yes[X] No[ ]

EMBEDDED ITEMS Yes[X] No[ ]

Description: steel reinforcing bar
Condition : Clean[X] Corroded[ ] Decayed[ ]
Size (mm) : 14 mm diameter
Location/Orientation: Depth of 5 mm in horizontal direction.
Other :

GENERAL COMMENTS: * Results are based on a visual examination of a core section only, and not all items listed above could be evaluated.

Distribution: ~~Mr. E.J. McColm~~ ~~Civil Research~~
Mr. J. Vitanyi Civil Research
Mr. M.F. Everitt Civil Research
842.5 SAB KR 163
842.5 (P) Official Record

Approved by: _____ Submitted by: _____
Report No.: SN91-24-K

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
ADAPTED FROM: ASTM C 856

Project: SIR ADAM BECK GS 1 - CHIPPAWA INTAKE Job No.: 42-196-281
Region : CENTRAL Area: LINCOLN File No.: 842.5 SAB
Structure: DIFFUSER SECT. DECK Report No.: SN91-25-K Date Issued: 91.07.15

Sample Type : Core[X] Cylinder[ ] Chunk[ ] Other[ ]

Sample Description: Section (interval 300 to 390 mm, nominal 96 mm diameter) of Core 10 drilled vertically from the diffuser section deck. The concrete has undergone approx.70 years of exposure in an environment of high rel. humidity.

*Sample Preparation: Freshly broken/saw cut/drilled surface[X] Polished face[ ]
Weathered surface[ ] Thin Section[ ]/No.

CONCRETE

Hit with hammer	: Ring[X]	Dull[ ]		
Break with fingers	: Particles not dislodged[X]	Powdery[ ]	Friable[ ]	
During sawing	: Clean cut[ ]	Breaks easily[ ]		
Cement/coarse aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Cement/fine aggregate bond	: Good[X]	Partial[ ]		Poor[ ]
Presence of honeycombing	: Not observed[X]	Minor[ ]		Extensive[ ]

COARSE AGGREGATE

Source	: River-run, Niagara River, Buffalo, N.Y.			
% of total volume	: 40-50 %	Visual estimate[X]		Point count[ ]
Material type	: Gravel[X]	Quarried[ ]	Mixture[ ]	Other[ ]
Shape	: Rounded[X]	Partly crushed[ ]		100% Crushed[ ]
Distribution	: Even[X]	Uneven[ ]		Chaotic[ ]
Nominal size	: 20 (mm)			
Maximum size	: 20 (mm)			
*Preferred orientation	: Present[X]	Not observed[ ]		

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS/GEL/ FRACTURES	REMARKS
Limestone/ dolomite.	30-40	None.	--
Chert of cherty carbonates.	30-40	None.	--
Quartzite	20-30	None.	--
Sandstone	10-15	None.	--
Gneiss	10-15	None.	--

FINE AGGREGATE

Source	: River-run, Niagara River, Buffalo, N.Y.				
% of total volume	: 25-35 %	Visual estimate[X]			Point count[ ]
Material type	: Natural[X]	Manufactured [ ]	Mixture[ ]		Other[ ]
Shape	: Rounded[X]	Subrounded[ ]	Subangular[ ]		Angular[ ]
Distribution	: Even[X]	Uneven[ ]			Chaotic[ ]
*Preferred orientation	: Present[ ]	Not observed[X]			

CEMENT MATRIX

% of total volume : 15-20 % Visual estimate[X] Point count[
Appearance of broken surface: Subtransluescent[ ] Dull[X] Chalky[
Colour : Grey[ ] Light grey[X] White[ ] Brown[ ] Other:
Colour distribution: Even[X] Mottled[ ] Gradational[
Bleeding : Extensive[ ] Minor[ ] Not observed[X
Carbonation : Surficial only[ ] Along fractures[ ] Partial[ ] Total[
Slag cement : Observed[ ] Not observed[X]
Fly ash : Observed[ ] Not observed[X]

VOIDS

% of total volume : 1-3 % Visual estimate[X] Point count[
Distribution : Even[ ] Uneven[X] Clustered[
Shape : Spherical[ ] Nonspherical[ ] Ellipsoidal[ ] Irregular[X
Entrained air : Air-entrained[ ] Non-air-entrained[X]
Interior lustre : Dull[X] Shining[ ]
Interior condition: Empty[X] Lined[ ] Partly filled[ ] Totally filled[
% Voids with mineralization: Most[ ] About half[ ] Few[ ] None[X
Mineralization : Alkali-silica gel[ ] Ettringite[ ] Portlandite[
Calcium carbonate[ ]

CRACKS

Amount : Extensive[ ] Occasional[ ] None[X
Continuity and Distribution:

Orientation : Vertical[ ] Horizontal[ ] Random[
Location : Through aggregate particles[ ] Around aggregate particles[
Width (mm) : Range to Average
% filled : %
Filling material: Alkali-silica gel[ ] Ettringite[ ] Portlandite[
Calcium carbonate[ ] Other:
Associated with embedded items: Yes[ ] No[ ]

EMBEDDED ITEMS Yes[ ] No[X]

Description:
Condition : Clean[ ] Corroded[ ] Decayed[
Size (mm) :
Location/Orientation:
Other :

GENERAL COMMENTS: * Results are based on a visual examination of a core sectio
only, and not all items listed above could be evaluated.
** Several elongated particles are orientated with their long axis
perpendicular to the direction of concrete placement.

Distribution: ~~Mr. E.J. McColm~~ ~~Civil Research~~
Mr. J. Vitanyi Civil Research
Mr. M.F. Everitt Civil Research
842.5 SAB KR 163
842.5 (P) Official Record

Approved by: _____ Submitted by: _____
Report No.: SN91-25-K

ONTARIO HYDRO RESEARCH DIVISION
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
ADAPTED FROM: ASTM C 856

Project: SIR ADAM BECK GS 1 - CHIPPAWA INTAKE Job No.: 42-196-281
Region : CENTRAL Area: LINCOLN File No.: 842.5 SAB
Structure: NORTH RETAINING WALL Report No.: SN91-26-K Date Issued: 91.07.15

Sample Type : Core[X] Cylinder[ ] Chunk[ ] Other[ ]

Sample Description: Section (interval 320 to 460 mm, nominal 96 mm diameter) of Core 12 drilled vertically from the north retaining wall. The concrete has undergone approx.70 years of exposure in an environment of high rel. humidity.

*Sample Preparation: Freshly broken/saw cut/drilled surface[X] Polished face[ ]
Weathered surface[ ] Thin Section[ ]/No.

CONCRETE

Hit with hammer	: Ring[X]	Dull[ ]	
Break with fingers	: Particles not dislodged[X]	Powdery[ ]	Friable[ ]
During sawing	: Clean cut[ ]	Breaks easily[ ]	
Cement/coarse aggregate bond	: Good[X]	Partial[ ]	Poor[ ]
Cement/fine aggregate bond	: Good[ ]	Partial[X]	Poor[ ]
Presence of honeycombing	: Not observed[ ]	Minor[X]	Extensive[ ]

COARSE AGGREGATE

Source	: River-run, Niagara River, Buffalo, N.Y.			
% of total volume	: 45-55 %	Visual estimate[X]		Point count[ ]
Material type	: Gravel[X]	Quarried[ ]	Mixture[ ]	Other[ ]
Shape	: Rounded[X]	Partly crushed[ ]		100% Crushed[ ]
Distribution	: Even[X]	Uneven[ ]		Chaotic[ ]
Nominal size	: 20 (mm)			
Maximum size	: 20 (mm)			
Preferred orientation	: Present[ ]	Not observed[X]		

LITHOLOGICAL TYPE	% OF COARSE AGGREGATE	REACTION RIMS/GEL/ FRACTURES	REMARKS
Limestone/ dolomite.	25-35	A few fractured particles Fractures do not extend into the cement paste.	--
Chert or cherty carbonates.	25-35	Same as above.	--
Quartzite	15-20	None.	--
Sandstone	15-20	None.	--
Gneiss	15-20	None.	--

FINE AGGREGATE

Source	: River-run, Niagara River, Buffalo, N.Y.				
% of total volume	: 35-40 %	Visual estimate[X]			Point count[ ]
Material type	: Natural[X]	Manufactured [ ]	Mixture[ ]		Other[ ]
Shape	: Rounded[X]	Subrounded[ ]	Subangular[ ]		Angular[ ]
Distribution	: Even[X]	Uneven[ ]			Chaotic[ ]
Preferred orientation	: Present[ ]	Not observed[X]			

CEMENT MATRIX 2 of 2

% of total volume	: 10-15 %	Visual estimate[X]	Point count[ ]
Appearance of broken surface:	Subtransluescent[ ]	Dull[X]	Chalky[ ]
Colour	: Grey[ ] Light grey[X] White[ ] Brown[ ] Other:		
Colour distribution	: Even[X]	Mottled[ ]	Gradational[ ]
Bleeding	: Extensive[ ]	Minor[X]	Not observed[ ]
Carbonation	: Surficial only[ ]	Along fractures[ ] Partial[ ]	Total[ ]
Slag cement	: Observed[ ]	Not observed[X]	
Fly ash	: Observed[ ]	Not observed[X]	

VOIDS

% of total volume	: 4-6 %	Visual estimate[X]	Point count[ ]
Distribution	: Even[ ]	Uneven[X]	Clustered[ ]
Shape	: Spherical[ ] Nonspherical[ ]	Ellipsoidal[ ]	Irregular[X]
Entrained air	: Air-entrained[ ]	Non-air-entrained[X]	
Interior lustre	: Dull[X]	Shining[ ]	
Interior condition	: Empty[X] Lined[X]	Partly filled[ ]	Totally filled[ ]
% Voids with mineralization	: Most[ ]	About half[ ] Few[X]	None[ ]
Mineralization	: Alkali-silica gel[X]	Ettringite[ ]	Portlandite[X]
	Calcium carbonate[X]		

CRACKS

Amount	: Extensive[ ]	Occasional[ ]	None[X]
Continuity and Distribution:			
Orientation	: Vertical[ ]	Horizontal[ ]	Random[ ]
Location	: Through aggregate particles[ ]	Around aggregate particles[ ]	
Width (mm)	: Range to	Average	
% filled	: %		
Filling material	: Alkali-silica gel[ ]	Ettringite[ ]	Portlandite[ ]
	Calcium carbonate[ ] Other:		
Associated with embedded items:	Yes[ ] No[ ]		

EMBEDDED ITEMS Yes[ ] No[X]

Description:			
Condition	: Clean[ ]	Corroded[ ]	Decayed[ ]
Size (mm)	:		
Location/Orientation:			
Other	:		

GENERAL COMMENTS: * Results are based on a visual examination of a core section only, and not all items listed above could be evaluated.

Distribution: Mr. E.J. McColm, Civil Research
Mr. J. Vitanyi, Civil Research
Mr. M.F. Everitt, Civil Research
842.5 SAB, KR 163
842.5 (P), Official Record

Approved by: _____

Submitted by: _____
Report No.: SN91-26-K